



**UNIVERSITI PUTRA MALAYSIA**

**HYDROMETEOROLOGY OF TROPICAL MONTANE RAINFORESTS OF  
GUNUNG BRINCHANG, PAHANG DARUL MAKMUR, MALAYSIA**

**SANAR KUMARAN A/L KOLANDAI**

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GUNUNG BRINCHANG, PAHANG DARUL MAKMUR, MALAYSIA**

**By**

**SANAR KUMARAN A/L KOLANDAI**

**Thesis Submitted to the School of Graduate Studies, Universiti  
Putra Malaysia, in Fulfilment of the Requirements for the Degree  
of Doctor of Philosophy**

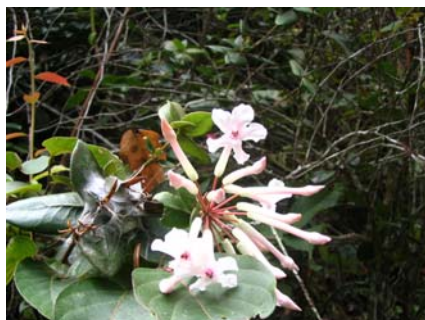
**July 2008**



## DEDICATION

*This thesis is dedicated to the Lotus feet of  
His Holiness Swami Sivanandaji Maharaj,  
His Holiness Swami Chidanandaji Maharaj and  
His Holiness Swami Jivanmuktanandaji Maharaj.*

*I wish to express my joyful gratitude for the loving support, patience and  
untiring sacrifice of my parents, Mr. Kolandai Periyathambi and Mrs.  
Paravathambal Narayanasamy. My wife, Kavita Subramaniam, for her  
unconditional support, love, patience and for what I am, when I am with  
her.*



**Ola i ka wai a ka 'ōpua.**

*There is life in the water from the clouds.*

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy.

**HYDROMETEOROLOGY OF TROPICAL MONTANE RAINFORESTS OF  
GUNUNG BRINCHANG, PAHANG DARUL MAKMUR, MALAYSIA**

By

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**July 2008**

**Chairman: Associate Professor Ahmad Ainuddin Nuruddin, PhD**

**Faculty: Forestry**

In tropical montane forests, the negative impacts of climate change on biological diversity have been documented as a result of declining trend of cloud water interception. The objectives of this study were to describe the microclimate; quantify the hydrometeorological processes; determine the cloud water interception and describe elements of the canopy water balance model of two contrasting montane forest types in Cameron Highlands, Pahang, Malaysia. This study was conducted at two sites: lower montane forest (LMF: 1600 m a.s.l.; 4°30.25'N, 101°23'E) and an upper montane forest (UMF: 2031 m a.s.l.; 4°31'N, 101°23'E) of Gunung Brinchang. Using standard weather stations and louvered fog gauges, rainfall,  $P$  (mm), cloud water interception  $CWI$  (mm), air temperature  $T$  (°C), relative humidity  $RH$  (%), wind speed  $\mu$  (m/s) and solar radiation  $R_s$  (MJ/m<sup>2</sup>/day) were recorded continuously at the two study sites from 1

November 2003 through 28 February 2005. In addition, throughfall  $Tf$  (mm) and stemflow,  $Sf$  (mm) in 0.02 ha forest plots were estimated weekly. Vegetation structure of trees ( $\geq 5$  cm diameter) at both study plots were carried out. During the 16 month study period, a total of 2612 mm and 2736 mm of rainfall was recorded at the LMF and UMF sites, respectively. Storms (median duration 1.12 hr at LMF and 0.83 hr at UMF) were of low intensity (mean 1.72 mm/hr at LMF and 1.43 mm/hr at UMF). The results of diurnal and seasonal variation of rainfall show that more than 80% of the total rainfall occurred in the afternoon until late night (1200 to 2300 hrs). Amounts of cloud water intercepted by the canopy of LMF and UMF were estimated at 1.5% and 8.6% of  $P$  and were significantly different. The mean solar radiation for the LMF and UMF sites were, 11.9 MJ/m<sup>2</sup>/day and 10.3 MJ/m<sup>2</sup>/day, respectively. Consistently, lower air temperatures were recorded at the UMF site (14.3 to 16.2°C) compared to LMF (16.7 to 18.1°C), due to elevation differences.

Total throughfall,  $Tf$  was 62.1% of rainfall in the taller LMF site and did not differ statistically from the stunted UMF site with 63.8%. The corresponding total stemflow ( $Sf$ ) amounts varied significantly for LMF and UMF sites, with 2.2% and 30.6% of rainfall, respectively. The rainfall interception,  $Ei$  at LMF was 37.4% of rainfall while at UMF; it was 5.7% of rainfall. Penman-Monteith evaporation ranged from 0.4 – 4.0 mm/day at

LMF and 0.7 – 3.3 mm/day at UMF, respectively and was not significantly different. In conclusion, the study shows no difference in total rainfall and throughfall between LMF and UMF. However, significant differences were recorded in the 24-hour readings of cloud water, air temperature, relative humidity, solar radiation, wind speed and evaporation indicating altitudinal difference of the study sites. Quantitative evidence was obtained for the first time in Malaysia on selected elements of canopy water balance and a new eco-hydrological canopy water balance for Malaysian montane rainforests is proposed.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia  
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**HIDROMETEOROLOGI HUTAN HUJAN TROPIKA MONTIAN  
GUNUNG BRINCHANG, PAHANG DARUL MAKMUR, MALAYSIA**

Oleh

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**Julai 2008**

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Di hutan hujan montain, kesan negatif akibat perubahan cuaca terhadap kepelbagaian biologi berhubung rapat dengan pengurangan pintasan awan. Objektif kajian ini adalah untuk meneliti iklim mikro, mengkuantifikasikan proses hidrometeorologi yang beroperasi, menentu kadar pintasan awan sertaimbangan air kanopi di dua hutan montain yang berbeza di Gunung Brinchang, Cameron Highlands, Pahang, Malaysia. Tapak kajian terletak di hutan montain rendah (LMF: 1600 m atas paras laut; 4°30.25'N, 101°23'E) dan hutan montain atas (UMF: 2031 m atas paras laut; 4°31'N, 101°23'E) yang berhampiran dengan puncak Gunung Brinchang. Berdasarkan data stesen kaji cuaca serta ukuran tolok pintasan awan, curahan hujan, pintasan awan, suhu udara, kelembapan bandingan, kelajuan angin serta radiasi solar pencerapan secara

berterusan dari 1 November 2003 hingga 28 Februari 2005 telah dilakukan. Jatuhan langsung ( $T_f$ ) dan aliran batang ( $S_f$ ) di plot hutan 0.02 ha yang berhampiran diukur setiap minggu secara manual. Struktur vegetasi semua pokok-pokok garispusat  $\geq 5$  cm telah diteliti di kedua-dua plot tapak kajian. Sepanjang kajian selama 16 bulan, hujan sebanyak 2612 mm (tapak LMF) dan 2736 mm (tapak UMF) direkod. Curahan hujan (median 1.12 jam di LMF dan 0.83 jam di UMF) intensiti rendah (purata 1.72 mm/jam di LMF dan 1.43 mm/jam di UMF) dicatat. Hasil kajian variasi harian menunjukkan lebih 80% hujan di tapak kajian turun pada sebelah tengahari hingga ke tengah malam (1200 ke 2300 jam). Jumlah pintasan awan kanopi LMF dan UMF dianggarkan 1.5% dan 8.6% dari jumlah hujan, serta berbeza secara signifikan. Purata radiasi solar harian di kedua-dua tapak kajian ialah 11.9 MJ/m<sup>2</sup>/hari (LMF) dan 10.3 MJ/m<sup>2</sup>/hari (UMF). Suhu udara di UMF sentiasa lebih rendah (14.3 – 16.2°C) berbanding LMF (16.7 – 18.1°C), disebabkan perbezaan ketinggian.

Sepanjang kajian, jatuhan langsung diukur sebanyak 62.1% dari jumlah hujan di tapak LMF dan tidak berbeza secara signifikan dengan tapak UMF yang merekod sebanyak 63.8%. Jumlah aliran batang pula berbeza bagi kedua-dua tapak kajian, iaitu 2.2% dan 30.6% dari jumlah hujan, masing-masing di tapak LMF dan UMF. Pintasan hujan,  $E_i$  di LMF dijangka



sebanyak 37.4% dari jumlah hujan dan 5.7% di tapak UMF. Kadar sejatan Penman-Monteith dianggarkan sebanyak 0.4 – 4.0 mm/hari di LMF dan 0.7 – 3.3 mm/hari di UMF, dan tidak berbeza secara signifikan. Rumusan kajian ini menunjukkan jumlah hujan dan jatuhan langsung tidak berbeza secara statistik diantara kedua tapak kajian. Walaubagaimanapun, purata harian pintasan awan, suhu udara, kelembapan bandingan, radiasi solar, kelajuan angin dan sejatan berbeza secara signifikan disebabkan perbezaan ketinggian di antara kedua-dua tapak kajian. Buat pertama kali di Malaysia, bukti kuantitatif diperolehi untuk imbangan air kanopi hutan montain tropika dan imbangan air kanopi eko-hidrologi untuk hutan montain Malaysia dicadangkan.

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I certify that an Examination Committee has met on 4 July 2008 to conduct the final examination of Sanar Kumaran a/l Kolandai on his Doctor of Philosophy thesis entitled "Hydrometeorology of Tropical Montane Rainforests of Gunung Brinchang, Pahang Darul Makmur, Malaysia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the Doctor of Philosophy.

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Date: 11 September 2008

## **DECLARATION**

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institution.



---

**SANAR KUMARAN A/L KOLANDAI**

Date: 29 September 2008

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